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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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INFORMATION CIRCULAR

SAFETY IN BLASTING AT AJO, ARIZ.

BY

ALLEN D. LOOK AND J. HOWARD BIRD

I. C. 7431,
February 1948.

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SAFETY IN BLASTING AT AJO, ARIZ.[1]

By Allen D. Look[2] and J. Howard Bird[3]

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7431."

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1987

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INTRODUCTION

The Phelps Dodge Corp. New Cornelia Branch open-pit copper mine operated without a fatality in the drilling and blasting department from December 13, 1937, to April 1, 1947, and continuing.

Between the dates named the explosives crews had a total of 746,520 man-hours of exposure and handled 12,000 tons of explosives, over 770,000 detonators, 2,300,000 feet of fuse, and 7,700,000 feet of Primacord in loading holes to break 116,780,000 tons of material.

It is the purpose of this paper to record the precautions taken to insure safe handling of explosives at this operation where safety is definitely a matter of forethought rather than chance.

GENERAL INFORMATION

The New Cornelia Branch open-pit mine operates on a large, low-grade, disseminated-copper deposit about one-half mile south of Ajo, Ariz. The pit is approximately oval, the ore body being some 4,800 feet long and 2,750 feet wide. Ore is mined with electric shovels loading into railroad cars. All benches in the pit are 40 feet in height except two, which are 60 feet high.

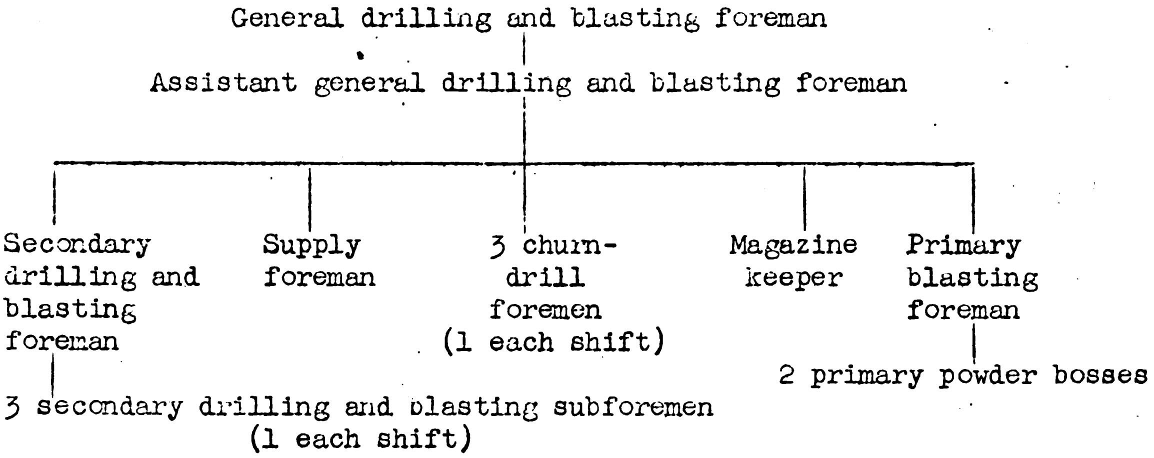
The New Cornelia ore body differs from most porphyry-copper deposits in being hard and siliceous. In common with the other low-grade porphyry-copper deposits, continued operation is possible only with economical handling of large tonnages. This has necessitated a great deal of study in the evolution of a safe and efficient method of handling the large quantities of explosives needed in breaking this hard-rock material.

ACKNOWLEDGMENTS

The authors wish to express their appreciation for the courtesies shown them by the mine officials and employees of the company.

EXPLOSIVES SUPERVISION

All use of explosives comes under the drilling and blasting department, with a supervisory organization as shown in the following chart:


General drilling and blasting foreman
Assistant general drilling and blasting foreman
Secondary drilling and blasting foreman
Supply foreman
3 churn-drill foremen (1 each shift)
Magazine keeper
Primary blasting foreman
2 primary powder bosses
3 secondary drilling and blasting subforemen (1 each shift)

EXPLOSIVES USED

Types of explosives used are varied in accordance with the various rock formations to be blasted. Water resistance must also be taken into account in selecting explosives, as impervious rock formations retard drainage, and water is found in about 90 percent of the holes to be loaded. A saving is effected where softer formations and dry holes will permit using lower-cost, free-flowing explosives, but such loading is done only when there will be no sacrifice of safety due to such use. The following table shows the explosives now in use:

Description	Strength, percent	Cartridge size and weight	Use
Special gelatin in sticks	40	1-1/4 by 12 in. 3/4 lb.	Used in blasting air-drill holes in medium-hard ground.
	60	1-1/4 by 12 in. 3/4 lb.	Used in blasting air-drill holes in hard ground.
Special gelatin in bulk	40	8 by 18 in. 50 lb.	Used in blasting churn-drill holes in medium-hard ground.
Same as above but packaged in large containers for handling by loading machine at New Cornelia mine.	60	8 by 18 in. 50 lb.	Used in blasting churn-drill holes in hard ground.

Description	Strength, percent	Cartridge size and weight	Use
No. 1 Amogel having a lower velocity and 33 percent more bulk as compared with the special gelatin.	60	8 by 22 in. 50 lb.	Used in dry churn-drill holes and also in water provided they are not allowed to remain in the water over 8 hours before being detonated.
Straight gelatin	60	8 by 18 in. 50 lb.	Used in adobe shots.
LDX 705 bag powder	70		Used in dry holes requiring a strong explosive.

All primary blasts are detonated by Primacord. Secondary blasts are detonated by either Primacord or cap and fuse. Primacord is detonated by electric detonators in primary blasting and by cap and fuse or electric detonators in secondary blasting.

STORAGE

Permanent Magazines

Two permanent magazines with a combined capacity of 600,000 pounds are used for the storage of explosives. Both are served by a good access road and also a railroad siding. All shipments of explosives to the mine are made by rail, and upon arrival at the Ajo depot the railway cars containing explosives are immediately taken over the company transportation system to one of the magazines. When the cars are switched at the magazines at least one car must be between the explosives car and the locomotive, so that the locomotive never enters the magazine enclosures.

Both magazines have adobe-brick walls 18 inches thick built on substantial foundations and covered with 1-1/2 inches of cement plaster on each side of the walls. Ceiling boards 3 inches thick support a sand tray filled with 8 inches of tailings. Ventilation is furnished by offset, screened openings near the floor level and screened cupolas in the roof. The wooden roofs are covered with galvanized sheet metal and aluminum, painted. The floors consist of matched hardwood flooring laid on boards 2 inches thick. Magazines are large enough to insure storage in such a manner that inventories may be readily taken and the oldest explosives may be used first. The date of manufacture is stamped on each case of explosives.

The magazine doors are made of two thicknesses of 1/4-inch boilerplate with 2 inches of wood at one magazine and 2-1/2 inches of wood at the other. Each door is locked with a shielded padlock. The gates in the wire enclosure are also locked with padlocks.

Both magazines are enclosed by woven-wire fence on steel posts and topped with several strands of barbed wire. The premises are marked by signs mounted on the fence and so located that a bullet passing through the face of the sign would not hit the magazine. Boxes with several compartments are hund on the fences near the gates where everyone entering the magazine area is required to deposit matches and smoking articles.

The magazines are in the waste-disposal area adjacent to the mine. One magazine is barricaded by its location in a rock-cut and the other is in a depression in the waste dump. The area surrounding the magazines is either rocky or covered with tailings so that there is no vegetation, and it is floodlighted at night.

A magazine keeper is assigned to the supervision and care of the explosives magazines. He keeps records of all deliveries to and from the permanent magazines and carries out the following instructions, which are posted at the entrance gate of each magazine:

1. Allow no one to enter this magazine without a written pass signed by the Mine Superintendent, or the General Drilling and Blasting Foreman, except the following:

    A. Men who are employed in the powder department and who have to enter the magazine in direct connection with their work.

    B. The Mine Superintendent.

    C. The General Mine Foreman.

    D. Members of the Safety Department.

2. All visitors entering with a pass must be accompanied by someone authorized by the Mine Superintendent, the General Mine Foreman, or the General Drilling and Blasting Foreman unless they are in the personal charge of any of the above executives, or are accompanied by a member of the Safety Department.

3. Do not carry matches, or allow others to carry matches or to smoke in, or near this magazine. It shall be the responsibility of the employee of the Company who accompanies visitors to make sure that the visitors comply with this regulation.

4. Employees and visitors shall put their lighters, matches, etc., in the box provided for that purpose which is bolted to the gate of the powder magazines and on the wall of the cap magazines.

5. Under no circumstances allow a primed cartridge, or detonating caps of any kind in this magazine.

6. When artificial light is needed use only an electric flashlight, or an electric lantern.

7. If a leak develops in the roof or walls, report it at once.

8. Keep the ground around the magazine clean of all trash.

9. Keep the magazine clean. Sweep it out not less than once a week, using a sweeping compound.

10. Keep the magazine securely locked at all times when not working in it.

11. Handle explosives carefully; do not drop, throw, or slide them.

12. Store powder boxes flat, top side up, corresponding grades and brands to be stored in such a manner that brand and grade will show to enable easy counting and checking. The oldest stock must be used first.

13. Allow no loose powder of any kind, or opened boxes in this magazine.

14. Any boxes of powder received in bad condition should be stored in the portable magazines until they can be used.

15. Keep any tools necessary for the erection, or changing of powder conveyors in the box provided for that purpose.

16. Keep the thermometer in the magazine and record highest and lowest temperature on the daily reports.

A maximum-minimum thermometer is kept inside the No. 2 magazine, and readings are recorded by the magazine keeper each day the magazine is opened. A study of these records shows a maximum daily variation of 9° and an average daily variation of about 4°. Exposure to any great seasonal variation is prevented by the fact that explosives handled through these magazines average less than 3 months from manufacture to use. The extreme range of magazine temperatures over a year's time was from a low of 47° to a high of 99°. During the same period the U. S. Weather Bureau readings at Ajo ranged from a low of 26° to a high of 112°.

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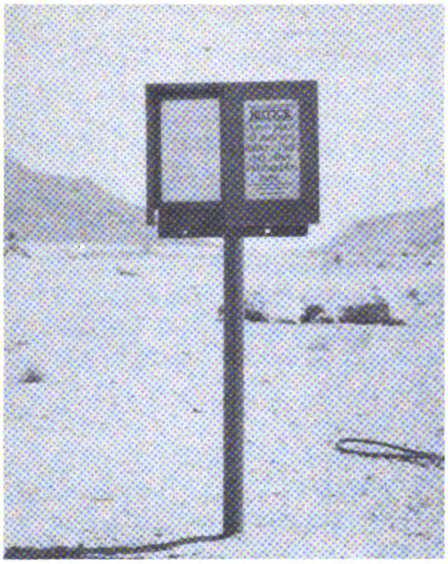

Figure 1. - Magazine rules and match-depository box mounted on steel post near detonator magazine.

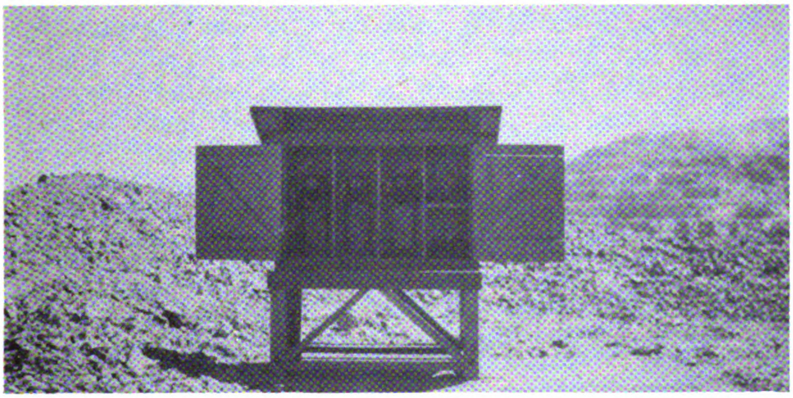

Figure 2. - Typical distributing magazine for storage of capped fuse.

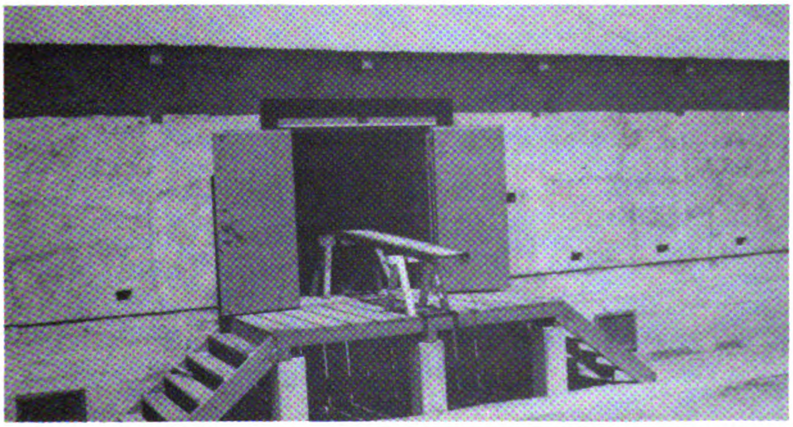

Figure 3. - Loading platform at No. 2 magazine, showing conveyor in place with conveyor frame

Detonator Magazine

Detonators are stored in a remodeled railroad boxcar in an isolated part of the dump area. The magazine has been plastered inside and outside for fire resistance and is ventilated by a roof ventilator. Safety fuse is stored in this magazine in quantities up to 100,000 feet. Detonator storage does not exceed 100,000 of both electric and fuse-type No. 8 detonators. All detonating fuse is stored in the explosives magazine in quantities up to 500,000 feet.

A combination storage box and bulletin board is mounted on a post near the magazine. The box is provided to hold matches, lighters, or similar articles while their owners are in the magazine. The bulletin board has the magazine rules displayed under glass. The rules posted are the same as the first 10 listed as displayed at the explosives magazines, with an additional rule prohibiting the storage of Primacord or any other detonating fuse in the detonator magazine. (See fig. 1.)

Distributing Magazines

Secondary storage of explosives and detonators is provided by 16 distributing magazines. These wooden magazines are distributed as needed about the open pit and are quite conspicuous because of their bright red color and yellow markings. Magazines are set as needed and always located at least 50 feet apart. Explosives are stored separately from detonators, and at this operation Primacord is always stored with the explosives. The magazines vary from the usual box type in that they are set on legs and have double doors forming the front of the magazine. This allows the workmen to remove or place explosives without bending; and a shelf arrangement in the explosives magazine makes it less likely that older explosives will be covered and left in the magazine while explosives recently placed in the magazine are taken for use. (See fig. 2.)

Rules governing the use of these magazines are posted at each magazine. The rules for the explosives magazine are given as follows:

1. The amount of powder kept in this magazine must not exceed twelve boxes.

2. Primacord can be stored in this magazine in quantities not to exceed four rolls.

3. No capped fuse, or caps of any kind shall be kept in this powder magazine.

4. The minimum distance between this magazine and a portable cap magazine shall be fifty feet.

5. If a leak develops anywhere in this magazine, or any part of it is broken or does not operate properly, report it to your foreman as soon as possible.

6. Keep the ground around this magazine clear of rubbish for a distance of at least twenty-five feet.

7. No powder boxes, or rubbish of any kind shall be burned, or any kind of a fire be built within one hundred feet of this magazine.

8. Make sure that the magazine is securely locked before leaving it.

At the detonator magazine, the last five rules are the same as those posted at the explosives magazine but at these locations the first three rules are as follows:

1. This magazine is for the storage of capped fuse and electric caps only.

2. It must not be used for the storage of powder of any kind or of detonating fuse.

3. No more capped fuse shall be stored in this magazine than can be placed on the pegs provided for that purpose.

TRANSPORTATION

Explosives

All portions of the mine may be reached from the network of supply roads, and explosives are delivered by truck to the point needed. Explosives for primary blasts are delivered directly to the loading area at the start of the shift. Explosives used in secondary blasting are procured from the distribution magazines, and deliveries are made by truck as needed to replenish the stock in these magazines. Primacord is delivered with the explosives.

In addition to the general requirements of good maintenance, safe operation, and carrying of fire extinguishers applied to all vehicles operated in the open pit the following specific rules are applied to trucks transporting explosives:

A truck hauling explosives must be plainly marked in the approved manner.

A truck hauling explosives must be moved with extreme caution and never at a rate exceeding 15 miles per hour.

Crews operating a truck loaded with explosives must preserve all clearance possible between their truck and other operating machinery.

Regardless of circumstances a truck loaded with explosives must never be left unguarded.

All vehicles used in transporting explosives must display red flags.

Explosives must be handled promptly without undue delay in transit.

No vehicle transporting explosives shall be overloaded. The General Powder Foreman shall specify the number of boxes which can be hauled by each vehicle, and this number must not be exceeded.

Any truck used in transporting explosives shall be inspected daily in order to determine that it is in proper condition; particular attention being paid to brakes and steering gear.

No unauthorized person shall ride on vehicles transporting explosives.

Gasoline tanks on vehicles should not be filled while explosives are on truck except in emergency.

No other material shall be hauled on trucks or cars loaded with explosives.

Explosives shall not be handled or transported during an electrical storm.

Vehicles used in transporting explosives shall be provided with wooden floors and proper flags.

All employees will remain a safe distance away from explosives in transit and will notify powder department employees of any fire or other hazards in the path of powder carrying vehicles.

In addition to the wooden floors required by the rules, wooden racks are furnished to fit the bodies of trucks transporting explosives, so there is no internally exposed metal.

In the magazines roller conveyors are used for moving explosives in and out of the magazine. The conveyor has a metal frame and wooden rollers and is built in sections, making it possible to erect the conveyor on the substantial horses provided so as to reach from a truck or railroad car at the loading platform to any part of the magazine. When the conveyor is set up, the metal sides are grounded by being connected to a ground wire at the front end of the loading platform. (See fig. 3.)

Capped Fuses

Two employees work full time on cutting and capping fuse and delivering capped fuse and electric detonators for use in the mining operation. All fuse is cut and capped in a building used only for that purpose, located about 300 feet from the detonator storage magazine. Rules previously quoted for the detonator magazine are applied also to the fuse-capping building.

Fust is cut from 3,000-foot spools in 5-foot lengths and capped with a bench-mounted hand-operated crimper. Capped fuses are made up daily and only the number needed for that day are prepared. Capped fuses are prepared for transportation in rolls of 10 and are carried in canvas bags to the portable magazine in the open pit. This delivery is made on foot, and electric detonators are placed in the portable magazines in the same way.

PRIMARY BLASTING

Drilling

Holes for primary blasts are drilled by churn drills, using a 9-inch diameter bit. This large diameter eliminates the necessity of springing, as the hole readily accommodates enough explosive below shovel grade to give satisfactory blasting performance. Holes are drilled 6 feet below shovel grade on the 40-foot benches and 8 feet below on the 60-foot benches. Where it is necessary to case through broken material in starting a hole, 10-inch casing pipe is used. Such casing is not removed before blasting as it is usually found undamaged by the blast.

Loading

A loading scheme for each primary blast is computed in advance of the loading operation by the general drilling and blasting foreman or his assistant, with the explosives calculated as to type and quantity for each hole to be blasted. The type and amount of explosives used depend on the hardness of the formation, whether the holes are wet or dry, and the amount of burden. Deck charges are used where needed to fragment the upper portion of the bench. The average primary blast uses 11,450 pounds of explosives, although blasts using over 100,000 pounds have been fired.

Data on a typical primary blast have been listed as follows:

Type of material		Monzonite
Number of churn-drill holes		39
Average height of bench	feet	40
Average depth of holes	do.	46
Average depth below floor	do.	6
Hole spacing	do.	15
Distance from crest	do.	12
Distance from toe	do.	18
Pounds explosives used		11,450
Loading calculation	lb. per cu. yd. of burden	7/8

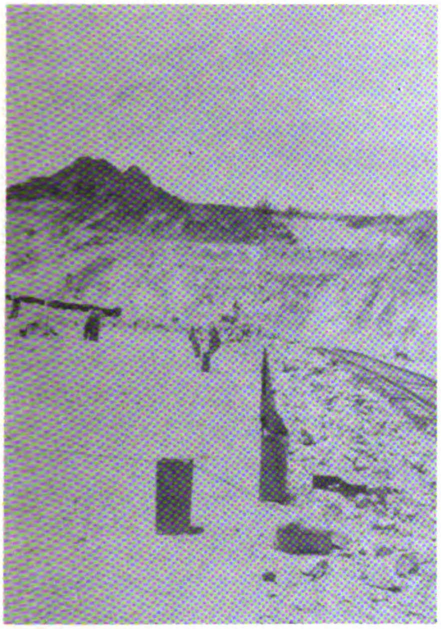

Figure 4. - Typical loading area for primary blast defined by red cord and red flags.

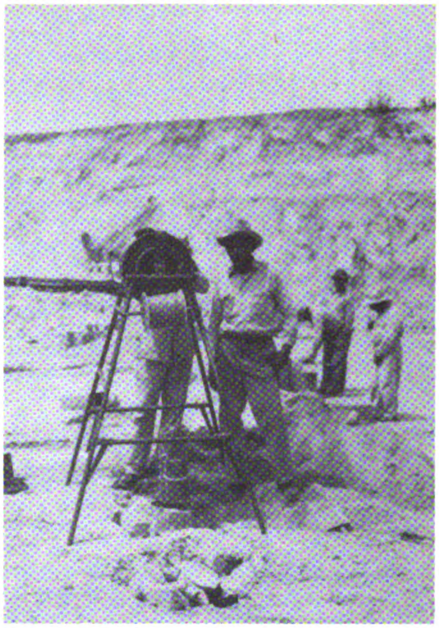

Figure 5. - Loading machine in operation lowering 50-pound cartridge. Primacord reel shown just in front of loading-machine drum.

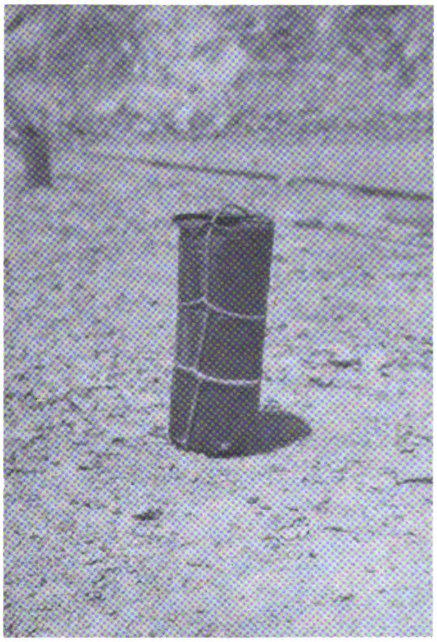

Figure 6. - Fifty-pound cartridge of explosives, 8 by 22 inches in size, showing jute cord tied around cartridge to facilitate lowering with loading machine.

Primacord	feet	3,000
Tons broken per pound of explosives		4.62
Tons broken per foot drilled		37.8

The area surrounding the holes to be loaded is cleared and defined as a loading zone. No persons other than employees of the blasting department are allowed in the loading zone except by permission of the foreman in charge. All material not necessary to the loading operation is removed. A red marker rope is supported around the boundaries of the loading zone, a large red flag visible from any point in the open pit being placed at each end of the zone. All primary blasts are made during daylight hours and explosives are delivered to the loading zone prior to the start of loading operations. The usual procedure is to deliver the explosives at the start of the day shift and loading is started immediately after delivery. (See fig. 4.)

Explosives are unloaded within the loading zone and stacked in accordance with the following rule:

> Explosives are unloaded and stacked at a point at least fifteen feet from the collar of the hole to be loaded and at least fifteen feet from any loaded hole. When a single series of holes is loaded, each stack contains enough cartridges to load at least two holes. When a multiple series is being loaded, each stack will contain enough cartridges to load at least four blast holes. In all cases, a distance of thirty feet is maintained between stacks.

At present, explosives are shipped in pasteboard containers and opened by use of a linoleum knife. If explosives are received in wooden boxes, wooden hammers and wedges are used for opening. Empty containers are immediately removed from the loading area and piled for later burning.

Free-flowing bag explosives are poured into the holes, but cartridges must be lowered. This lowering is facilitated by having the 50-pound cartridges tied at the manufacturer's plant with jute cord and by the use of an ingenious loading machine. Fifty-pound cartridges are either 8 by 18 inches or 8 by 22 inches in size, depending on the type of explosives being used. Jute cord, tied around the cartridges, makes a large-mesh, but secure, basket which provides a convenient loop for handling and attaching the lowering hook. (Fig. 5.)

The explosives-loading machine consists essentially of a drum for winding the 3/8-inch cotton lowering rope, rotating on a shaft, all supported on a 1-inch pipe mounting. A spring inside the drum is wound by the weight of the cartridge being lowered into the hole and provides the energy for rewinding the rope. Speed of lowering is controlled by the operator by means of a brake band on the drum operated by a hand lever. A brass lowering hook is so designed as to release when the rope is slacked. A roll of Primacord is mounted on a shaft built into the framework of the loading machine near the drum, where it is convenient for fastening to the cartridge and unwinds readily as the cartridge is lowered. The loading machine is carried easily by the two-man loading crew by means of hinged handles which fall as soon as the machine is set down. (See fig. 6.)

In the operation, the loading machine is set over the hole so that the hook will center over the hole. The empty hook is then lowered to the bottom of the hole to determine the depth. A previous examination has been made by the foreman, using light reflected by a mirror to show if there are any obstructions which might interfere with loading. The explosives are removed from the shipping cases by one man, who moves just ahead of the loading crew. The jute-cord sling of the cartridge is examined for loose knots or weak spots. One member of the crew attaches the brass hook to the jute-cord sling of a 50-pound cartridge, which is then suspended over the hole. If this is the first explosive to be loaded, Primacord is tied with one full turn around the cartridge and in such a manner as to be held in place by the jute cord. This primer cartridge is lowered carefully, with one man passing the Primacord through his hand as it unwinds to see that it is kept clear of the rope and casing. With the primer on the bottom of the hole, the Primacord is cut off with some 6 feet left above the collar and the end suitably anchored on the surface. A paper pad is placed under the Primacord at any hole where it passes over the edge of the casing. The remainder of the cartridges are then lowered until the loading of the hole is completed.

The loading machine was first designed as a safety measure to eliminate the previous practice of cutting and dropping high explosives into deep churn-drill holes. After being put in use it was discovered that loading time was reduced 30 percent, the use of large cartridges gave a better seal with 10 percent more explosive below shovel grade, and "powder" headaches amongst employees were virtually eliminated since it was no longer necessary to open the explosives wrapper.

All holes are stemmed to the collar with tailings left by a leaching plant operated at the property until 1930. This 3-mesh material has a yellow color and gives good visibility against the gray ore body. On blasting, the stemming is disseminated through the broken ore and is not noticeable. There have been no misfires in primary blasting at this property since 1939, but the distinctive color of the stemming would be a good indicator to the shovel operator if a misfire should occur. Stemming is delivered to a steel loading bin at the open pit by railroad car and transported to the blasting sites by dump truck before loading operations are started.

Blasting

The branch lines from the holes are not connected to the mainline Primacord more than 30 minutes before the blast is scheduled to be fired. Connections are made according to manufacturer's recommendations. Two independent checks and counts of the connections are then made by the powder bosses. All connections must be approved by these men, and the counts must check each other and also with the number of holes loaded. With the

350-foot blasting line laid out but not connected to the blasting battery, the final connections are made by first connecting the electric detonator to the blasting line and then to the Primacord main line. The blasting line is not connected to the battery until the foreman has given the actual blasting signal. The blasting zone is considered as an area extending at least 300 feet in all directions from the loading zone.

The blasting procedure followed is quoted from company orders as follows:

> a. Two blast-zone watchmen shall be sent to each level both above and below the center of the blast zone.
>
> b. Until the blast warning signals have been completed, these men shall remain together.
>
> c. When the warning whistles have been sounded, the two men on each level then separate and each man, walking in the direction opposite that taken by his partner, shall clear the section of the level he is on.
>
> d. When his section of the level is entirely cleared he shall wait for the "all clear" signal from the man on the next level below him, if he is below the loaded zone, or the man above him if he is above the loaded zone.
>
> e. The all clear signals shall start from the two men on each level most distant from the loaded zone.
>
> f. The signals shall travel from watchman to watchman on each successive level approaching the loaded zone. The watchman on each level nearest the loaded zone shall give their signals directly to the powder foreman or bosses on the loaded zone.
>
> g. The powder foremen or bosses on the loaded zone shall observe this entire proceeding carefully and when they have received all the signals and are absolutely sure that their section of the blasting zone is clear, they shall exchange "all clear" signals with each other.
>
> h. When this has been done, the signal to light the fuses or connect the electric caps shall be given.
>
> i. When this procedure has been carried out to clear a zone for a primary blast the powder bosses or powder foreman shall remove themselves from the blast zone as soon as possible after completing final connections on the electric caps.

j. When they are in the clear of the blast zone they shall give "all clear" signals to the primary powder foreman who is to be stationed at a point from which he has been able to view the entire clearing of the blast zone, and from which point he can be easily seen by the man who has been designated to throw the switch to fire the blast.

k. When the primary powder foreman has received all clear signals from the primary powder bosses, he shall satisfy himself that the blast zone is absolutely clear before giving the foreman in charge the signal to fire the shot.

The blasting warning signals mentioned in (b) above are given by a series of short whistle blasts at two locations. One whistle used is a large air whistle audible to all pit employees, at the train dispatcher's office overlooking the entire mine pit. The second signal, given by a similar series of whistle blasts blown on the power shovel whistle nearest the blast, gives the location of the blast. Following the blast an all clear signal is given by the same whistles.

After blasting, the bank is sprinkled with water to allay dust and sprinkling is continued while either ore or waste is being loaded. The annual rainfall averages 10 inches and affords little help in this connection.

SECONDARY BLASTING

Drilling

Secondary blasting is largely the blasting of boulders too big to pass through the shovel dipper. The usual practice is to drill these boulders with jackhammer-type drills, using 2-inch-diameter detachable bits. All drilling is done wet. Where there has been a shortage of labor during the last few years, it has not always been possible to drill all the boulders to be shot, and in some cases "bulldozing" or "adobe" shots are also made. In connection with the secondary blasting of boulders, some experimental work has been done in the use of shaped charges, and while the results have been promising that method of blasting is not generally used.

Before the drilling operations loose or dangerous material on the bank above the area is scaled down and the supervisor inspects the bank. Careful watch of the bank is continued by the subforeman during drilling and loading.

Loading

In secondary blasting the area immediately surrounding the holes to be blasted is considered the loading zone. This loading zone is cleared of all material not needed in the loading operation prior to loading. Each secondary powderman is furnished with a red flag 2 by 4 feet in size, mounted on a 5-foot staff. These flags are used to signify that explosives are being loaded and designate the area as a loading zone. Powdermen on night shift are provided with permissible electric cap lamps.

Holes are loaded with 1-1/4- by 12-inch sticks of explosives, or parts thereof, tamped with wooden, rubber-tipped tamping sticks and stemmed to the collar with fine material taken from the pit floor. The proportionate quantity of explosives used in each drill hole depends upon the depth of the hole and the size of the boulder to be broken. The quantity of explosives used is kept to a minimum to prevent, as much as possible, the hazard of excessive throwing of rock. Primers are made up just before placing in the hole.

When bulldozing or adobe shots are made, 50-pound cartridges are cut into desired amounts and placed as needed. This type shot is used only when the shape of the boulder indicates that it will be easily broken by detonation of a small placed charge; the average charge of this type is 3-1/2 to 4 pounds of explosives.

Blasting

Secondary blasts are detonated by Primacord, cap and fuse, or a combination of the two. The agent used depends upon the number of powdermen available and the number and location of the boulders to be blasted. One powderman is allowed to ignite 10 or fewer fuses on smooth ground or 8 or fewer on rough ground, but in all cases at least two powdermen must be present. Excess holes may be connected with Primacord and the Primacord in turn detonated by cap and fuse. The full 5-foot fuse is used on most holes; but in "adobe" blasting the fuse may be trimmed a few inches to insure that these shots go before flying material from other holes dislodge the exposed explosives. Fuses are ignited from a 15-inch spitter. Because of the limitation on the number of holes, the men experience no difficulty in lighting their quota of fuses well under the time limitation but are instructed to leave when this 15-inch fuse burns out, regardless of any possible holes remaining to be lit.

All secondary blasts use the same procedure in firing as quoted under primary blasting, except that a whistle signal from the train dispatcher's office is not given. The only whistle warning signal will be given by a power shovel in the vicinity of the blast, and then the number of shots to be fired is indicated by a corresponding number of short whistle signals. If a power shovel is not in the immediate vicinity of a pending blast, a portable whistle is attached to a connection in the compressed-air line and used to give the signal.

Where a secondary blast is in the vicinity of a primary loading zone, the blast must be completed before explosives are delivered to the primary zone or delayed until all explosives and stemming are in the churn-drill holes and all workmen have retreated from the primary zone. In some cases if conditions permit, primary and secondary blasts on the same bank are fired simultaneously.

Subforemen supervise the drilling and loading operations, but before the charges are detonated the powder foreman must be present to check the hook-up, check the number of shots to be ignited by each man, and direct the retreat of all other persons from the area. The powder foreman remains in the loading area to witness and supervise ignition of the fuses and is last to retreat.

The usual practice is to blast all secondary holes on the same shift in which they are loaded. However, if it is necessary to defer blasting until the next shift the following procedure is followed:

The drilling and blasting foreman or subforeman for the shift on which the holes were loaded will transmit information to the supervisor, relieving him as to number and general location of the loaded holes, and will designate a powderman from his crew to act as watchman over the loaded holes until properly relieved by the supervisor of the following shift. The powderman will show the man relieving him the exact location of all loaded holes and also pass on any other information pertinent to the safe completion of the blast.

Under no circumstances will any holes be blasted until all loaded holes have been accounted for.

After a secondary blast has been completed, an all-clear signal is given by means of the whistle used to give the warning signal.

SAFETY ORGANIZATION

The company maintains a safety department under the direction of a safety supervisor. The responsibility for safe operation rests with the supervising force, and safety-staff members are assigned duties in departments where their assistance will provide help for the operating supervisors. The safety staff also keeps a safety library of books, pamphlets, reports, films, and other educational material for use in the mine safety program.

Safety meetings are scheduled monthly. Foremen meet with their crews in groups called unit committees. Each unit committee has a subject assigned for discussion at the monthly meeting, with subject material furnished by the safety staff. Each unit committee has a secretary, and a record of all meetings is kept. A divisional committee meeting of the superintendent and all foremen is held following completion of the schedule of unit meetings.

The working areas and equipment are inspected at regular intervals by committees composed of foremen, workmen, and safety-staff members. A written report is made of the findings during the inspection, and recommendations are offered for correcting the hazards noted. Forms detailing the equipment of each department and the hazards to be looked for are provided to insure thorough inspection.

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All accidents are investigated, including those that do not result in personal injury, by investigating committees made up of personnel employed in the department where the accident occurred. Members of the inspection committees, investigating committees, and unit-meeting secretaries are rotated to enable as many workmen as possible to take an active part in the safety program.

A safety-suggestion system is conducted, with a record kept of all suggestions submitted and the disposition made of each one. Workmen are advised of the action taken on all suggestions submitted.

Every new employee is taken through a job-introduction program, at which time safe practices and procedures are discussed and the man is issued his rule book and personal safety equipment. A member of the safety staff takes the new man to the job and introduces him to his foreman.

Rules are incorporated in codes of safe practice covering the operation of each department. These codes are prepared with considerable care and cover not only safe practices but outline in detail the necessary steps in conducting safe and efficient operations.

Bureau of Mines first-aid classes are held during the winter months and all employees are encouraged to take the training.

CONCLUSION

The excellent accident experience in connection with use of explosives at the New Cornelia Branch has been obtained by adherence to the fundamental principles of having as few men as possible handle explosives, using trained and experienced men following a familiar standard procedure, and observation of the safety regulations pertaining to the use and handling of explosives. Compliance with the safety regulations is obtained both by a desire on the part of the crew to make the operation safe because of their knowledge of the hazard involved and by adequate supervision.

Safe explosives practices have evolved along with increased efficiency in the operation and have proved a help rather than a hindrance in the process. The Joseph A. Holmes Safety Association at its annual meeting in Washington, D. C. in April 1946 awarded the Drilling and Blasting Department of the Phelps Dodge Corporation, Ajo, Ariz., a Certificate of Honor "for working without a fatality in the drilling and blasting operations at an open-cut copper mine from December 13, 1937, to December 31, 1945, during which time 21,145,950 pounds of explosives were used in blasting 979,070 drill holes which broke 103,748,064 tons of material while employing an average of 33.8 men for 703,584 man-hours."